Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.14 Physical Metallurgy – Fall 2008

Quiz I

Friday, October 10, 2008

The Rules:

1) No calculators allowed

2) One hand written 3x5 index card may be prepared as a crutch

3) Complete 4 out of the 5 problems. If you do more than 4 problems, I will grade the first 4 that are not crossed out.

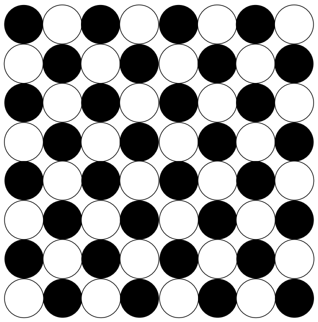
4) Make sure that you READ THE QUESTIONS CAREFULLY

5) Supplementary materials are attached to the end of the test (eqns., etc.)

6) WRITE YOUR NAME HERE:

Problem #1: Superdislocations!

In pure metals there is only one kind of atom, and the Burger's vector is therefore always one atomic spacing. What about in a chemically ordered, two-component solid (for example, NaCl, SiC, CuAu)? Here is a 2-D picture of an ordered solid.



Part A: Draw a 2-D picture of a full edge dislocation in such an ordered solid. (*Reminder- a full edge dislocation leaves the crystal undisturbed far away from the core*)

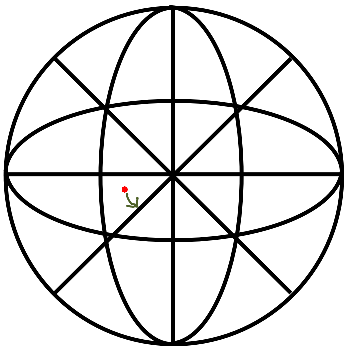
Part B: Draw a Burger's circuit around your full edge dislocation and label the Burger's vector.

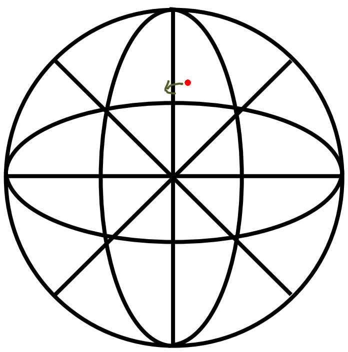
Part C: Do you think that this full dislocation would like to dissociate? Describe the forces/energetics involved in the choice of whether dissociation occurs or not. If yes, explain why and draw a picture of it. If no, explain why not.

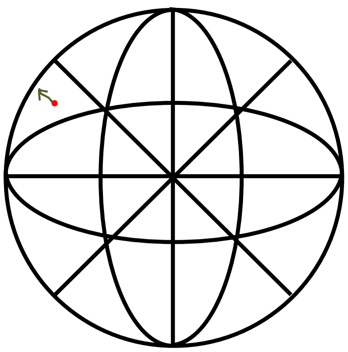
Problem #2: FCC or BCC?

Three different crystals, all of which are cubic (either FCC or BCC) are strained, and the orientation of the crystal is tracked. Each of them is strained in **compression**.

In the stereographic projections below, the results of these tests are shown. Identify whether you think the crystal is FCC or BCC, and explain briefly why in each case.



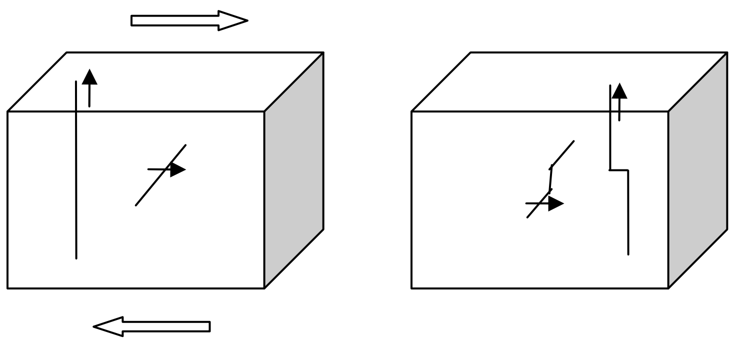




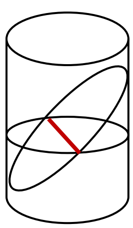
Problem #3: Unphysics

Each of these scenarios is unphysical. Explain what is wrong in each case, and correct it to make it physically correct. In each drawing, the arrow denotes the Burger's vector.

A) The small crystal at the left is stressed as shown. One dislocation moves to the right, intersecting another dislocation and leaving the structure shown at the right.

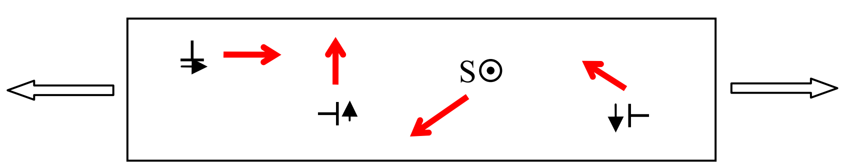


B) A single crystal is loaded in tension, and slip happens on two planes as shown. Dislocations run into each other and form a Lomer lock on the red line.



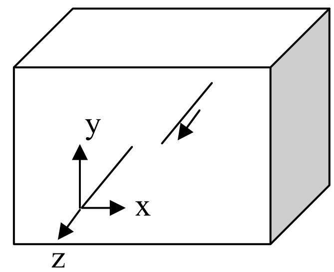
C) In the microscope, a dislocation loop is observed. The Burger's vector is not known. Over time, the loop expands spontaneously with no external load applied to the sample, due to the repulsive forces exerted by different parts of the loop on one another.

D) A small crystal contains a bunch of parallel dislocations, and is strained in tension. The dislocations move in the directions shown by the red arrows. The Burger's vectors are shown by the black arrows



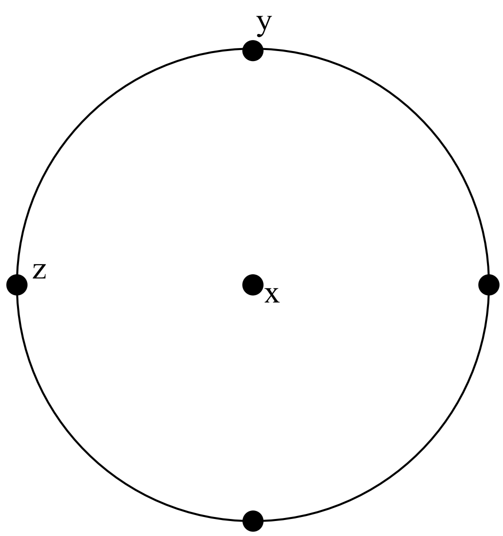
Problem 4: Wherein the Student Demonstrates Knowledge of Both the Stereographic Projection and Inter-Dislocation Forces

Here are two dislocations in a crystal. The coordinate system is defined to lie on one of them, as shown. They lie in different planes.



Now, notice that for the right dislocation, the Burger's vector is defined—it is a screw dislocation.

For the dislocation on the left, the Burger's vector is undefined. It can lie in any direction. In fact, it could lie anywhere on the stereographic projection.

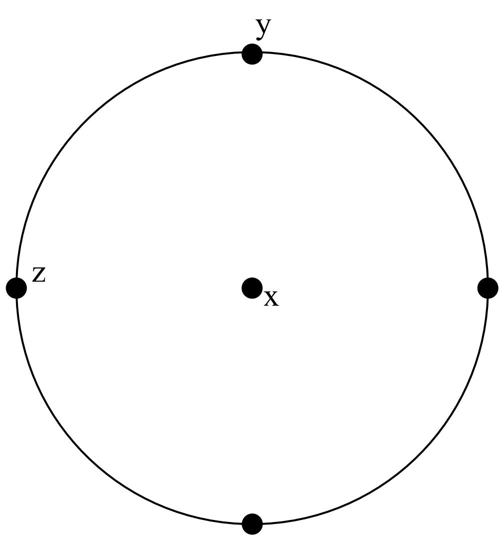


Part A:

Allow the Burger's vector of the left dislocation to vary over the stereographic projection at the left. On the projection, indicate how the interactive forces between the dislocations change with position in the projection. More specifically, draw in regions where the dislocations would be attracted to each other, repulsed from one another, or non-interacting.

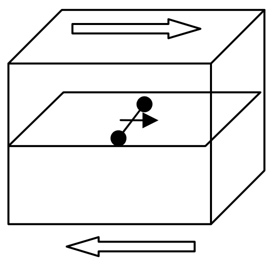
Part B:

Now add some more details to the projection: for regions where the dislocations are attracted or repelled, please mark regions of the diagram in which they will *actually move* in response to the interaction, and regions in which they will not move despite the forces they feel. A second copy of the diagram is provided if you need extra/clean space to work.

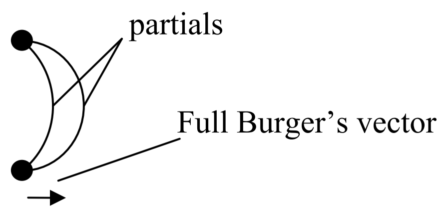


Problem 5: Frank-Read Redux

A dislocation segment is pinned at two pinning points, and is experiencing external stress that encourages bowing. Its Burger's vector is shown. This is the situation we covered in class that led to the Frank-Read Source.



Projection view



Top down view

Consider what happens if this is not a full dislocation, but rather is split into partials. For the full dislocation, the bowing goes until a local annihilation event occurs. How does this annihilation look for the dissociated dislocation? Draw some pictures and briefly walk though the sequence of events.

Helpful (?) Bonus Information

Stress field around an edge dislocation:

$$\sigma_{xx} = -\frac{\mu b}{2\pi(1-\nu)} \frac{y(3x^2 + y^2)}{(x^2 + y^2)^2}$$

$$\sigma_{yy} = \frac{\mu b}{2\pi(1-\nu)} \frac{y(x^2 - y^2)}{(x^2 + y^2)^2}$$

$$\sigma_{xy} = \frac{\mu b}{2\pi(1-\nu)} \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}$$

$$\sigma_{zz} = \nu(\sigma_{xx} + \sigma_{yy})$$

all other σ components are = 0.

Stress field around a screw dislocation:

$$\sigma_{rz} = \frac{\mu b}{2\pi r}$$

all other σ components are = 0, and note that $r^2 = x^2+y^2$

Forces between dislocations:
Parallel edge:

$$F_y = \frac{\mu b^2}{2\pi(1-\nu)} \frac{y(3x^2 + y^2)}{(x^2 + y^2)^2}$$

$$F_x = \frac{\mu b^2}{2\pi(1-\nu)} \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}$$

Parallel screw:

$$F_r = \frac{\mu b^2}{2\pi r}$$

Inspirational Quote:

"The dislocation plays a commanding role in those grandest of all deformations on Earth: the upheavals that have produced the mountain ranges and the continents themselves"

Johannes and Julia Weertman, pioneers in dislocation theory, 1964

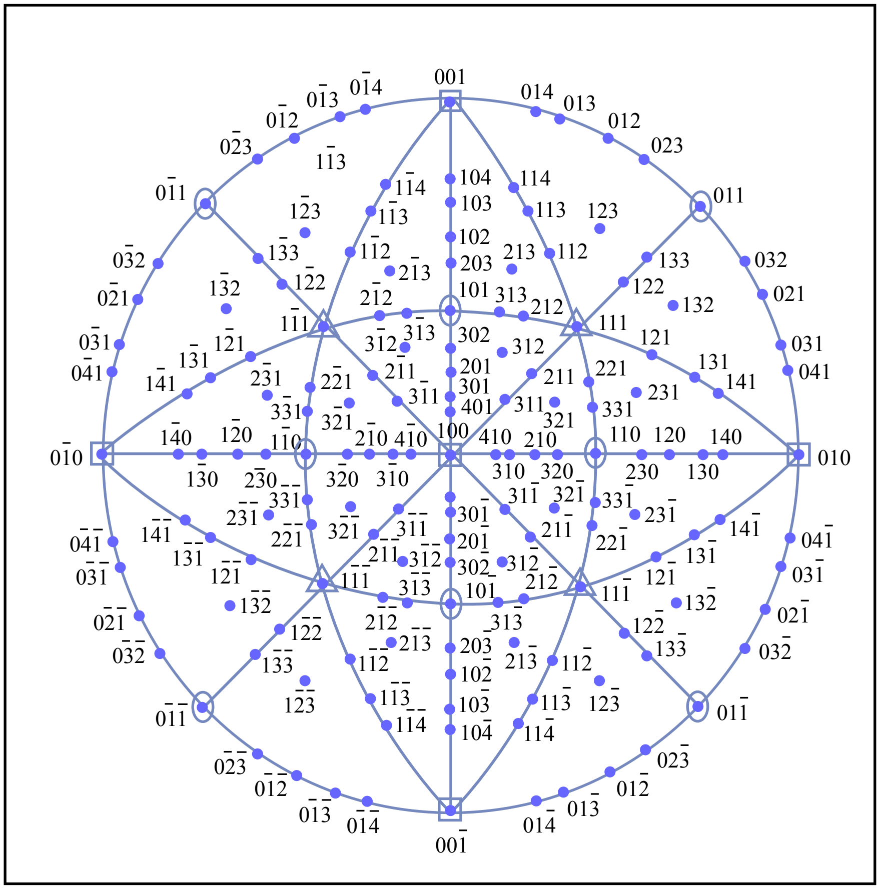


Figure by MIT OpenCourseWare.

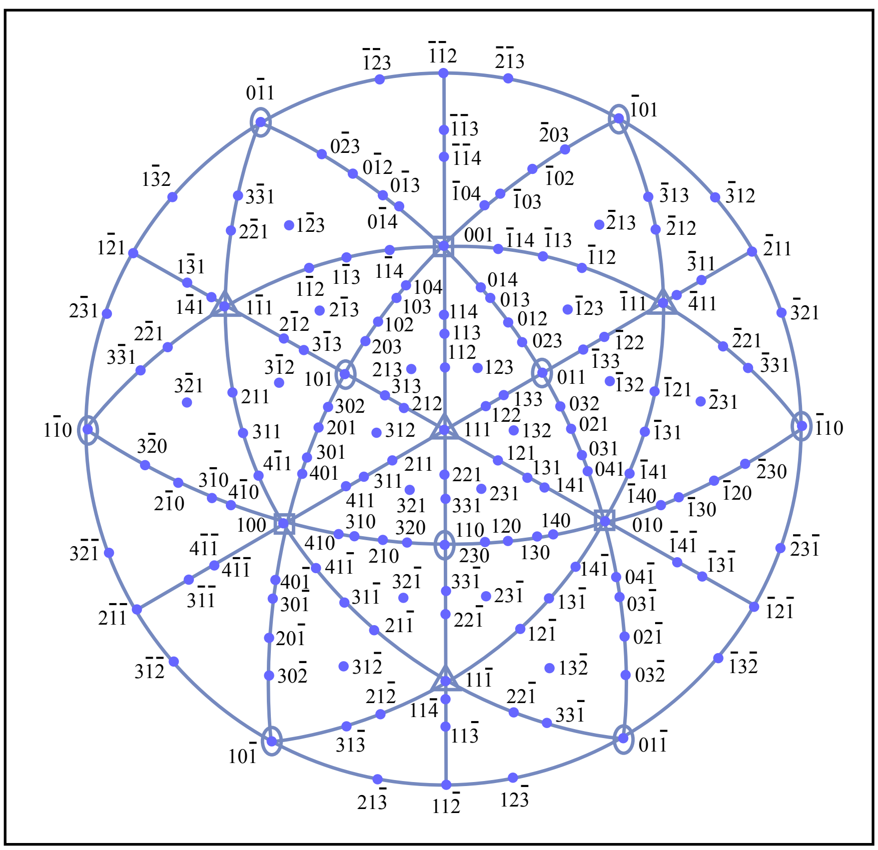


Figure by MIT OpenCourseWare.